ALLOWANCE FOR BOLL-WEEVIL DAMAGE.

Since South Carolina was entirely free from boll-weevil damage for most of the period covered by the data used in computing the constants of the regression equation, whereas such damage was considerable over the period of the test years, the comparatively large error between the actual and the estimated yield not only necessitates a correction for boll-weevil effects, but shows the soundness of the method, because a correction is required for the introduction of adverse crop effects not included in the investigation. In the absence of other exact data an allowance of 10 per cent for 1920 and 20 per cent for 1921 and 1922 brings the actual and calculated effects into close accord. We are satisfied that these allowances are fair ones and that the working reliability of the method and equation has been demonstrated.

The next step should be to apply these methods and equations to other oat, corn, and cotton States, and this will be done as soon as the data can be tabulated.

We are sure that the methods can be refined with more work, and also that they will need to be modified somewhat when working in districts with different climatic conditions. It seems to the writer, however, that the principle has been demonstrated and that after other important crop districts have been covered it will be possible to predict the yield of the important crops considerably before the harvesting time.

It will be seen in the studies noted above that although the weather must be taken into account up to about the harvest date for oats, the probable yield of corn can be determined by the end of July and of cotton at the end of June in the eastern part of the belt.

Undoubtedly the weather in July, and possibly August, must be considered in connection with cotton in the western part of the belt and that August may need to be taken into account in connection with corn in the central and western Great Plain States.

Figure 4 gives the variation of the calculated from the recorded yield of cotton in pounds of lint per acre in South Carolina for each year from 1899 to 1922, inclusive. The yields for 1920, 1921, and 1922 were calculated in advance.

THE DAILY QUANTITIES IN WHICH SUMMER PRECIPITATION IS RECEIVED.

By JOHN S. COLE, Agriculturist.

[U. S. Bureau of Plant Industry, Washington, D. C., November 15, 1922.]

SYNOPSIS.

The daily precipitation during the five months from April to August, inclusive, for the 12-year period from 1908 to 1919, inclusive, was studied at eight stations in the Great Plains and at Washington, D. C., Nephi, Utah, and Moro, Oreg. During 153 days of these months Washington had measurable precipitation on 55.8 days, the Great Plains on 41.7 days, Nephi on 26.3 days, and Moro on 21.8 days. Within limits, the quantity of precipitation is not determined by the number of days on which it occurs. In the Great Plains 82 per cent of the days having measurable precipitation have 0.50 inch or less and 45 per cent have 0.10 inch or less. In quantities from 0.05 inch up to a critical point, which is approximately 0.30 inch at Moro and Nephi, from 0.70 inch to 1.10 inches in the Great Plains, and 1.20 inches at Washington, the frequency of a given precipitation is inversely proportional to its amount. Above the critical point the decrease in frequency is more rapid than increase in amount. The number of precipitations below 0.05 inch increases with decreasing quantity but not in the same proportion.

In studying some of the results of the experiments in crop production conducted in the Great Plains by the Office of Dry-Land Agriculture Investigations of the Bureau of Plant Industry it became necessary to analyze the precipitation data in more detail than was afforded by monthly and seasonal totals. The points on which information was sought were (1) the frequency of precipitation and (2) the quantities of water received in precipitations of different amounts. The study was made on the precipitation for the five-month period from April to August, inclusive, for the 12 years from 1908 to 1919, inclusive. The eight field stations of the Bureau of Plant Industry, at which these studies of precipitation were made, are the Judith Basin station, near Moccasin, Mont.; Dickinson, N. Dak.; the Belle Fourche station, near Newell, S. Dak.; Akron, Colo.; North Platte, Nebr.; Hays, Kans.; Garden City, Kans.; and Amarillo, Tex. The North Platte record used in this study is the one from the rain gauge on the table where the dry-land experimental plats are located. All records were made from standard Weather Bureau rain gauges with free exposure and are a part of the records of the Biophysical Laboratory of the Bureau of Plant Industry obtained in cooperation with the Office of Dry-Land Agriculture Investigations. The five-month period from April to August, inclusive, was used because it is the period with which the study of the behavior of the grain crops is chiefly concerned. The study was made for 12 years because the eight stations selected for it had continuous records for that period; it seemed sufficiently long to give reliable averages and fairly smooth curves, and it was the period covered by the study of crops and soil moisture.

The precipitation is recorded in quantities received daily and consequently does not permit more refined study than of the number of days having precipitation of given quantities. In this paper a precipitation is therefore understood to be a day having precipitation of measurable quantity.

To afford comparison with other conditions the study was extended to include the Weather Bureau records of precipitation at Washington, D. C., as representative of humid conditions, and the records obtained at Nephi, Utah, and Moro, Oreg., in the cooperative work between the Office of Cereal Investigations and the agricultural experiment stations of those States and the Biophysical Laboratory of the Bureau of Plant Industry. These two stations are representative of the winter rainfall and dry summers of the intermountain dry-farming region.

The first study made of the data was a count of the number of precipitations in each of six groups, as follows: From 0.01 to 0.50 inch, from 0.51 to 1 inch, and then in groups of 1 inch up to 5 inches. There were none above 5 inches to be considered. The results of this study are shown in Table 1. To avoid fractions, the data in this table are shown on the basis of the total number in the 12 years during the months studied. The columns at the right show the average number of days each year having measurable precipitation in the 153 days from April 1 to August 31, inclusive, and the average precipitation during this period. Table 1 shows that the eight stations in the Great Plains have measurable precipitation on an average of 41.7 days during this period, or every $3\frac{2}{3}$ days. The range is from 36.8 days at Garden City and Amarillo to 47.6 days at the Judith Basin station. During the same period Washington, D. C., had precipitation on 55.8 days; Nephi, Utah, on 26.3 days; and Moro, Oreg., on 21.8 days. Significant differences are shown between the different stations or sections of the

Great Plains as well as between the Great Plains as a whole and the other regions having different quantities or types of rainfall. It is evident from it that within limits, as between different stations in the Great Plains, the quantity of precipitation is not determined by the number of days on which it occurs. The Dickinson and Belle Fourche stations have almost exactly the same number of days of precipitation, but the quantity at Dickinson is 2.27 inches, or 24 per cent, greater than at the Belle Fourche station. The latter place has the greater number of precipitations less than 0.50 inch and the former of precipitations between 1 and 2 inches. Exactly the same number of precipitations at the Belle Fourche and the Hays stations yield 9.27 inches at the former and 14.78 inches at the latter.

from 0.01 inch to 0.50 inch and 12 per cent within the next half-inch group it appeared desirable to study the distribution in more detail. The number of precipitations of each unit measurement (0.01 inch) was therefore determined. The number of precipitations multiplied by the quantity gave the amount contributed by that quantity to the total. Study of the material showed that satisfactory results could be obtained by combining the quantities into groups of 0.10 inch. The totals were divided by 12 to obtain the average annual contribution of each 0.10-inch group to the total precipitation for the five months. The data so obtained are shown in Table 2 for eight stations in the Great Plains and Washington, D. C., Nephi, Utah, and Moro, Oreg. The curves formed by successive additions of these quantities are plotted

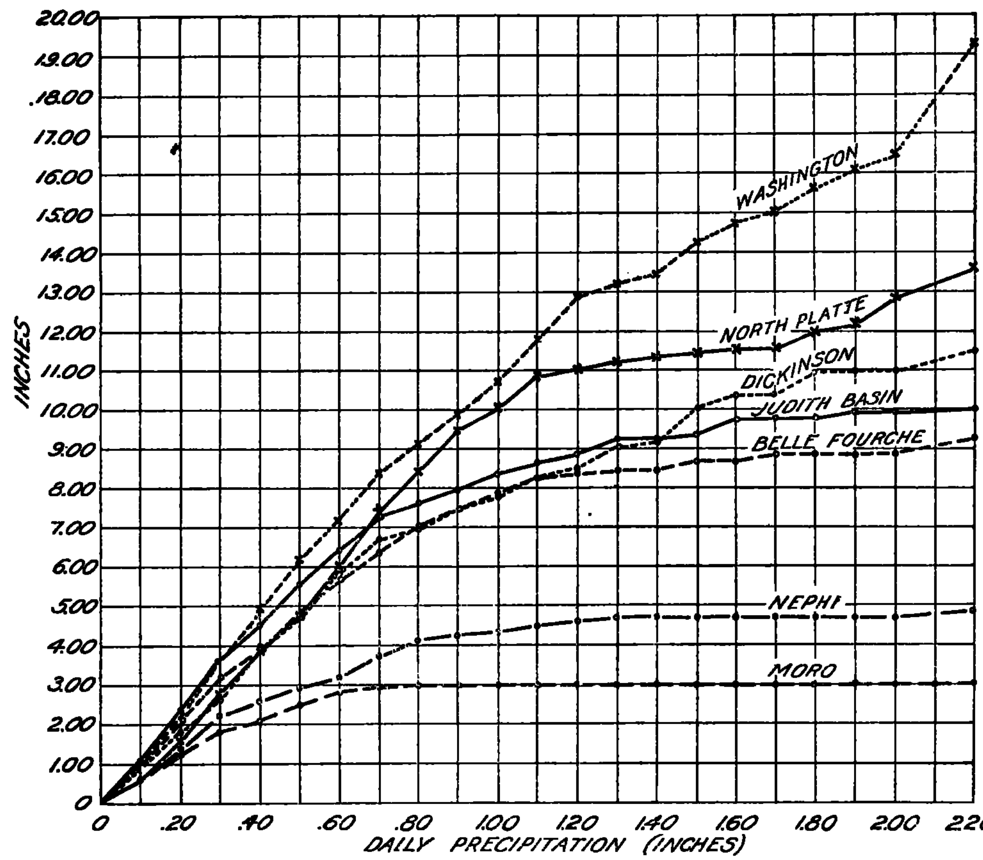

FIG. 1.—Precipitation received annually in the five months from April to August, inclusive, at seven stations, charted as accumulating totals of the quantities received in daily precipitations of different magnitudes.

One of the striking points shown in comparisons in the Great Plains is the comparatively small number of days having over 1 inch of precipitation at the Judith Basin and Belle Fourche stations. Another point is the comparatively large number of days having precipitation between 0.51 inch and 1 inch at Hays and North Platte.

Washington, D. C., has precipitation on a greater number of days than any station in the Great Plains, but it owes the greater part of its higher precipitation to an increase in the number of precipitation days of over 1 inch. The frequency of precipitation is only 17 per cent greater at Washington than at the Judith Basin station, but the quantity is 91 per cent greater.

The Nephi, Utah, and Moro, Oreg., stations each has a comparatively small number of precipitations, a small number or none of the larger quantities, and a small total.

Because so large a proportion, 82 per cent in the Great Plains, of the precipitations came within the one group

in Figure 1 for as many stations as can be shown without too much confusion of the curves. On account of the small number of precipitations amounting to more than 2 inches a day this study was carried only to that point, and quantities above it were included in single entries.

Moro, Oreg., in a region of winter rainfall, receives during the summer months less precipitation in each unit group than any of the other stations and receives none in daily quantities above 0.80 inch. Nephi, Utah, also in a region of winter rainfall but with a higher annual and summer precipitation than Moro, receives more in each group than that place but generally less than any of the stations in the Great Plains. In quantities of more than 1.30 inches a day it had during the period under study only one precipitation of 2.61 inches.

The precipitation of six of the stations in the Great Plains (Judith Basin, Dickinson, Belle Fourche, Akron, Garden City, and Amarillo) is much the same when considered in contrast to that at Hays and North Platte in the Great Plains, Washington, D. C., and Nephi and Moro in the intermountain area. There are, however, important differences between these six stations both in total quantity and in its distribution. In precipitations up to 0.60 inch a day the Judith Basin station receives more precipitation than any other of the Great Plains stations and only 0.73 inch less than Washington, D. C. The precipitation in quantities up to this amount, however, constitute nearly 64 per cent of the total at the Judith Basin station and only 37 per cent at Washington. Dickinson and Belle Fourche parallel each other very closely up to quantities of 1.20 inches. In rainfalls above that quantity daily Belle Fourche receives an average of only 0.87 inch a season, while Dickinson receives 2.99 inches. The higher seasonal precipitation at Dickinson is consequently due to a greater number of heavy rains. Table 1 shows that Dickinson has an average of 2½ rains of over 1 inch a season, while the Belle Fourche station has only one rain of such amount.

Dickinson and Akron parallel each other very closely throughout the entire range.

Amarillo and Garden City parallel each other fairly closely but with the Amarillo curve rising to a somewhat higher total.

TABLE 1.—*Number of days having measurable precipitation in the five months from April to August, inclusive, from 1909 to 1919, inclusive and the average precipitation during that period each year.*

Station.	Precipitation group.						Total number.	Average number per year.	Average precipitation.
	0.01 to 0.50 inch.	0.51 to 1 inch.	1.01 to 2 inches.	2.01 to 3 inches.	3.01 to 4 inches.	4.01 to 5 inches.			
									Inches.
Judith Basin, Mont.	506	50	14	1	0	0	571	47.6	10.12
Dickinson, N. Dak.	431	56	28	1	1	0	517	43.1	11.54
Belle Fourche, S. Dak.	450	53	10	2	0	0	515	42.9	9.27
North Platte, Nebr.	379	89	24	2	1	0	495	41.3	13.64
Akron, Colo.	416	58	22	5	1	0	502	41.8	11.89
Hays, Kans.	399	76	33	5	1	1	515	42.9	14.78
Garden City, Kans.	366	50	23	1	0	2	442	36.8	10.98
Amarillo, Tex.	348	65	25	3	1	0	442	36.8	11.92
Washington, D. C.	530	76	51	11	2	0	670	55.8	19.35
Nephi, Utah	285	25	4	1	0	0	315	26.3	4.96
Moro, Oreg.[1]	251	11	0	0	0	0	262	21.8	3.03

[1] The data at Moro are for the 12 years from 1910 to 1921, inclusive.

North Platte and Hays have higher seasonal precitation than the other stations. Their greatest departure from the other stations is in the zone of precipitations from 0.60 inch to 1.10 inches a day. At these two stations the quantity received in each group of 0.10 inch remains fairly constant up to 1.10 inches. The differences between the two may be significant or may be due to insufficient data to smooth the curves. In rainfall received in quantities of 1.10 inches or less daily they average only about 1 inch each season less than Washington, D. C., but in quantities above that amount Washington receives enough more to bring its average for the five months up to 19.35 inches, as compared with 14.78 inches at Hays and 13.64 inches at North Platte.

The groups of 0.10 inch afford an analysis more refined, perhaps, than is necessary for agricultural purposes, but while the data were in hand they were subjected to further study to determine the contribution of each measured unit of 0.01 inch precipitation a day to the total. The concern in this study was primarily with the smaller quantities, because as an average of the eight stations in the Great Plains 45 per cent of the days having measurable precipitation have precipitation of not over 0.10 inch. The study was carried to quantities of 1 inch. Even before this quantity is reached the number of precipitations is so reduced that the volume of data studied is not sufficient to produce satisfactorily smooth curves.

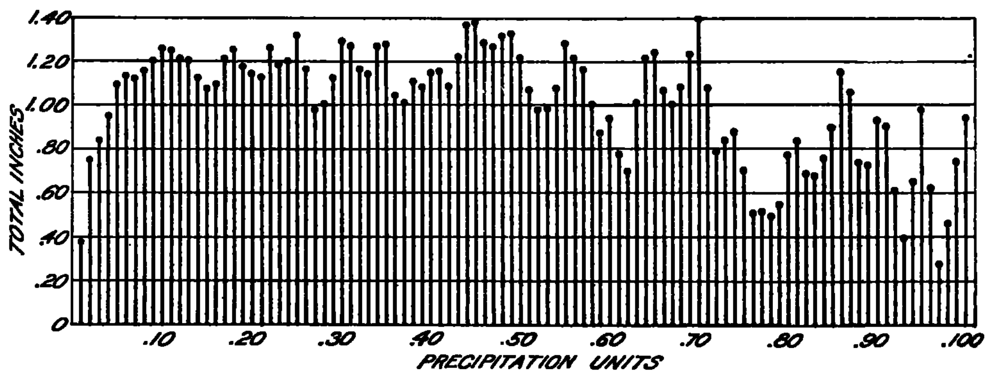

FIG. 2.—Total quantity of precipitation received in each measurable daily amount up to 1 inch during the five months from April to August, inclusive, in the 12 years from 1908 to 1919, inclusive, shown as the smoothed average of eight stations in the Great Plains.

The quantity of precipitation received in each unit amount was determined for the eight stations in the Great Plains and averaged. The figures so obtained were smoothed by the formula $b=(a+b+c)\ /\ 4$. To avoid fractions the calculations were carried through and the curve plotted on the basis of the total quantities received in the 12 years. Reduction to a yearly basis is not necessary, as the concern is with relative rather than absolute quantities.

TABLE 2.—*Amount of precipitation, in inches, received annually in each precipitation group during the months from April to August, inclusive, for the 12-year period from 1908 to 1919, inclusive.*

Precipitation groups.	Judith Basin.	Dickinson.	Belle Fourche.	North Platte.	Akron.	Hays.	Garden City.	Amarillo.	Great Plains average.	Washington.	Nephi.	Moro.[a]
0.01 to 0.10	1.08	0.91	0.99	0.72	0.91	0.69	0.74	0.62	0.83	0.98	0.63	0.55
.11 to .20	1.31	.91	1.10	.90	.97	.92	.78	.88	.97	1.23	.78	.70
.21 to .30	1.15	.84	1.08	1.16	.96	1.03	.88	.82	.99	1.39	.79	.55
.31 to .40	1.01	1.16	.70	.89	.76	1.04	1.11	.89	.95	1.36	.38	.32
.41 to .50	1.05	.91	.95	1.16	1.04	1.39	.84	1.15	1.06	1.26	.38	.37
.51 to .60	.86	1.11	.84	1.20	.70	.73	.68	.98	.89	.98	.27	.37
.61 to .70	.89	.92	.76	1.35	.60	1.04	.66	1.10	.92	1.21	.54	.11
.71 to .80	.31	.25	.64	1.06	.63	.69	.37	.76	.59	.74	.38	.06
.81 to .90	.36	.50	.42	1.07	1.00	1.27	.50	.50	.70	.78	.14	0.00
.91 to 1.00	.39	.32	.39	.55	.65	.95	.80	.40	.56	.81	.08	0.00
1.01 to 1.10	.26	.53	.44	.79	.79	.87	.27	.62	.57	1.04	.17	0.00
1.11 to 1.20	.19	.20	.09	.19	0.00	.48	.57	.19	.24	1.15	.10	0.00
1.21 to 1.30	.42	.52	.11	.21	.21	.42	.11	.10	.26	.32	.10	0.00
1.31 to 1.40	0.00	.11	0.00	.12	.45	.56	.34	.23	.23	.22	0.00	0.00
1.41 to 1.50	.12	.85	.24	.12	.24	.24	.36	.49	.33	.85	0.00	0.00
1.51 to 1.60	.39	.39	0.00	.13	.39	.77	.13	.39	.32	.51	0.00	0.00
1.61 to 1.70	0.00	0.00	.14	0.00	0.00	.14	.28	0.00	.07	.28	0.00	0.00
1.71 to 1.80	0.00	.59	0.00	.45	0.00	0.00	.15	.73	.24	.58	0.00	0.00
1.81 to 1.90	.16	0.00	0.00	.15	.30	0.00	.31	.15	.13	.46	0.00	0.00
1.91 to 2.00	0.00	0.00	0.00	.66	0.00	0.00	.17	0.00	.10	.33	0.00	0.00
2.01 up	.17	.52	.38	.76	1.29	1.55	.93	.92	.82	2.87	.22	0.00
Total	10.12	11.54	9.27	13.64	11.89	14.78	10.98	11.92	11.77	19.35	4.96	3.03

[a] The data at Moro are for the 12 years from 1910 to 1921, inclusive.

The results are plotted in Figure 2 by verticals raised from each amount to the quantity, as indicated by the marginal scale, received from it in 12 seasons. It will be noted that amounts from 0.05 inch to 0.70 inch per day contribute approximately equal quantities to the total precipitation. In other words, within these limits the frequency of precipitation is inversely proportional to its quantity. In a period having 20 days of 0.05 inch precipitation each there will be 10 days of 0.10 inch, 5 days of 0.20 inch, 4 days of 0.25 inch, and so on. The number of precipitation days below 0.05 inch increases with decreasing quantities but not in the same proportion. Table 2 and Figure 1 show that the upper limit of 0.70 inch to which this relation is limited is the minimum in the Great Plains and does not apply to all stations. At North Platte and at Hays the point at which the curve breaks is reached at 1.10 inches, and at Washington, D. C., at 1.20 inches. On the other hand, the critical point in the curve is reached at 0.30 inch at both Moro and Nephi.

The marked depression in the smoothed curve at 0.60 inch is due to the fact that some of the stations did not receive precipitation in quantities of 0.59 inch, 0.61 inch, and 0.62 inch.

Above the critical point, which varies with the station, the decrease in the frequency of precipitations is more rapid than increase in quantity, so that the product of the number of precipitations in a given time and their amount is a constantly decreasing quantity.

NOTE ON ATMOSPHERIC HUMIDITY IN THE UNITED STATES.

By ROBERT DE C. WARD.

[Harvard University, Cambridge, Mass., Oct. 21, 1922.]

Relative humidity.—Atmospheric humidity has many important relations to life—human, animal, and vegetable. It, to a considerable degree, affects our bodily comfort; our feeling of heat or cold. It is one of the controlling climatic influences in the growth and develment of crops and of all forms of plant life. Both directly and indirectly, it affects many of our activities, our industries, our commercial organization. Relative humidity, i. e., the ratio between the amount of moisture in the atmosphere and the amount which could be present, without condensation, at the same termperature and under the same pressure, is a direct expression of the physical moisture or dryness of climate in relation to its temperatures. Relative humidity is a real and definite factor in climate. It is directly indicated by organic substances. It reacts upon them. For this reason the human hair is commonly used in measuring relative humidity in the hair hygrometer. Other organic substances, such as catgut or certain vegetable fibers, may also be used in the same way. The cracking or swelling of woodwork with decrease or increase in relative humidity is well known.

The general system followed by the lines of equal relative humidity is simple. and easily remembered. (1) On the Pacific, Atlantic, and Gulf coasts the lines show a distinct tendency to parallel the seacoast. This feature is most clearly indicated on the Pacific slope, and there in the warmer months. (2) Over the interior plateau the lines group themselves in a general oval pattern around central or southern centers of minimum humidity. (3) Over the Great Plains lines of equal relative humidity lie more or less parallel with the meridians, especially in the central and southern sections. The geographical distribution of relative humidity, thus briefly outlined, depends on a number of controls. Among these (1) the temperature, (2) the direction of the prevailing winds, (3) the distance and direction of the chief source of moisture-supply, and (4) the topography are the most important.

The meridional trend of the relative humidity lines on the Great Plains was discovered by Loomis in 1880 in connection with his construction of the first chart of this kind for the United States.[1] The data upon which this pioneer chart was based related to a very few stations between latitudes 45° and 30° N., east of the Rocky Mountains, for January, 1875. Only four lines were drawn, viz, those for 50 per cent, 55 per cent, 60 per cent, and 65 per cent, but they were sufficient to indicate that "on the east side of these (Rocky) mountains there is a narrow belt of territory where the mean humidity is less than one-half; and there is a belt at least 400 miles wide where the mean humidity is less than two-thirds; and in advancing eastward we find the humidity to increase still further." This distribution is attributed to the fact that in crossing the Sierra Nevada the moisture, in the westerly winds, is "mostly condensed." "By passing over the Rocky Mountains there is a further condensation of vapor, so that when the air descends on the eastern side of these mountains it is almost destitute of moisture." The vapor brought from the Gulf of Mexico is diffused over the central lowlands and mixes with the dry air coming across the mountains from the west. Hence, in Loomis's opinion, the relative humidity must increase rapidly from the Rocky Mountains eastward.

Since Loomis's first attempt to draw relative humidity lines, numerous later charts have been published, covering all months as well as the year, and based on more and more complete data.[2]

The most complete discussion and cartographic and tabular presentation of the humidity element in the

[1] Elias Loomis: "Contributions to Meteorology, Being Results Derived from an Examination of the Observations of the United States Signal Service and from Other sources." *Amer. Journ. Sci.*, 3d ser. vol. 20, 1880, pp. 1-21. Pl. I.

[2] See, e. g., the following:

Frank Waldo: "Elementary Meteorology." 8 vo. New York, 1896. Fig. 114 shows average annual relative humidity in the United States, but no statement is made as to the source of the chart or the period covered by the observation.

H. A. Hazen: "The Distribution of Moisture in the United States." *Ann. Rept. Chief of Weather Bureau for 1897-98.* 4 to.

Washington, D. C., 1897, pp. 327-338: pls. VI, VII, diagrs. V-IX. The plates illustrate "waves of moisture, pressure, and temperature" for individual dates; the diagrams show fluctuations of dewpoint, of dewpoint and temperature, and diurnal range of moisture.

Frank H. Bigelow: "The Vapor Tension on the Sea Level, the 3,500-foot and the 10,000-foot Planes." *Ann. Rept. Chief of Weather Bureau for 1900-1901.* 4 to. Washington, D. C., 1902. Vol. II, pp. 420-422. Gives monthly and annual charts of relative humidity at sea level, and monthly and annual charts of normal vapor tension at sea level and on the 3,500-foot and the 10,000-foot planes.

Annual Report of the Chief of the Weather Bureau for 1901-02. 4 to. Washington, D. C. 1902, pp. 317-320. Three charts of normal relative humidity for January, July, and the year, based on data covering varying periods of time, from 4 to 14 years. Data given in tables. No author's name given, and no discussion.

Kenneth S. Johnson: "Mean Monthly and Mean Annual Relative Humidity Charts of the United States," *Rept. So. Afr. Assoc. Adv. Sci.*, 1906. 8 vo. Cape Town, 1907. pp. 161-168. Contains mean annual and mean monthly charts of relative humidity, based chiefly on the period 1888-1901, although in some cases shorter records were taken into account but given less weight. The data were not reduced to the true daily mean. Lines are drawn for differences of 10 per cent.

For tabulations and discussion of relative humidity data see, in addition to the above, the following:

W. B. Stockman: "Temperature and Relative Humidity Data." *U. S. Weather Bureau. Bulletin O.* 4 to. Washington, D. C., 1905. Pp. 29.

Alfred J. Henry: "Climatology of the United States." *U. S. Weather Bureau Bulletin.* Q 4 to. Washington, D. C., 1906. p. 61. Table VIII, pp. 106-109, contains the monthly mean values of relative humidity for 8 a. m. and 8 p. m., seventy-fifth meridian time, for a number of selected stations.